separate disease-germs and protective. These attempts have hitherto been fruitless in the case of rabies, but have been successful in other diseases. By cultivating disease-germs in a suitable liquid, and afterwards killing the germs themselves by heat, or removing them by filtration through porcelain, solutions have been obtained quite free from germs, and containing only the substances they have formed during their life and growth. Such solutions have been shown by M. Pasteur's pupils and others to have the power of protecting from septicæmia, anthrax, typhoid fever, and diphtheria; and Prof. S. Dixon, of Philadelphia, has succeeded in rendering animals resistant to inoculation with tubercle by previously inoculating them with the products of growth of the tubercle bacillus.

Most interesting experiments on the nature of these protective substances have been made by Wooldridge, Hankin, and Sydney Martin, who have shown that they are probably either globulins or albumoses rather than alkaloids, although Martin has obtained an alkaloid which produces all the symptoms of anthrax, and possibly may protect against it.

Koch's direction that his new remedy is to be prescribed under the name of paratoluid seems to indicate that it belongs to a class of bodies more nearly akin to alkaloids than to albumoses. Para-acet-toluid has been investigated by Jaffe and Hilbert, and found, like Koch's remedy, to be innocuous to the lower animals. It is possible that the new remedy may belong entirely to that class which has furnished us lately with so many valuable antipyretics and analgesics. But it seems more probable that it consists partly at least of a lymph containing the products generated by some microbe. One's first thought would naturally be that the substances formed by the tubercle bacillus itself would be chosen by Koch for curative as they have been by Dixon for protective purposes. But tubercle differs much from many other infective diseases, for anthrax, typhus, scarlet fever, or measles, run a definite course, and if they do not kill the patient at once, they protect him from a subsequent attack. But the attack of hectic fever which daily recurs in a patient suffering from phthisis confers no protection on him at all, but rather hastens the progress of the disease to a fatal termination.

The case is sometimes different when disease due to another microbe attacks a patient suffering from some form of tuberculosis. Thus lupus has been seen to shrivel and die after an attack of erysipelas or measles, and peritonitis, supposed to be tubercular, has disappeared during recovery from diphtheria. Judging from the resemblance between the effects of Koch's remedy and those of erysipelas, measles, or diphtheria, we should be inclined to suppose it to consist of a filtered culture of the germs of one of these or of some such infective disease, probably mixed with some kind of paratoluid.

It may perhaps seem idle to speculate on the composition of a remedy which its discoverer will probably describe fully ere long, but it must be remembered that tuberculosis, though one of the most frightful scourges of mankind, is not the only ill that flesh is heir to. There are others, with a less mortality perhaps, but even more feared by the sufferers themselves, and we may trust that the lines of research just indicated, whether they be exactly those on which Koch has been working or not, may lead to the discovery of certain cures for scarlet fever, diphtheria, gummata, and that most dreaded of all—cancer.

T. L. B.

THE CHEMISTRY OF IRON AND STEEL MAKING.

The Chemistry of Iron and Steel Making. By W. Mattieu Williams, F.C.S., F.R.A.S. (London: Chatto and Windus.)

THIS work differs materially from the ordinary technological text-books with which we are so familiar. Throughout it is evident that the author has thoroughly utilized his varied experience and great ability to their fullest extent, resulting in the production of a mass of suggestive information valuable to the ordinary student, and affording matter for reflection, even to those who have for years made the chemistry of iron and steel a specialty.

The introductory portion of the work is interesting, but chiefly briefly historical; the same may be said as regards chapter ii., on the ores of iron, which includes some speculations on the possible meteoric origin of iron. The wide diffusion of iron in the form of dust is quoted as indicating in part at least the meteoric origin of the metal.

Chapters iii. and iv., on reduction and dissociation, fluxing, roasting, and calcination, are thorough, giving concisely and forcibly the necessary knowledge in a manner well worthy of imitation in more pretentious works. The author's study on the analogy of dissociation to evaporation, commencing with water, followed by illustrations of the dissociation of the metals from their oxides, &c., shows that he not only clearly understands his subject, but also has the faculty of communicating his ideas clearly to others.

It is difficult to do justice to chapters v. and vi., on the blast-furnace, without entering into details which would here be out of place. The descent of the charge in the blast-furnace is first discussed, and the importance of clear ideas as regards the *rationale* of blast-furnace charging is insisted upon. It is not a simple process: (1) the heterogeneous impurities of the ore have to be removed; (2) the iron must be reduced to the metallic state; (3 and 4) the reduced metallic iron must be fused, as also the earthy impurities. All must proceed in due sequence. A definite statement of the problem of modern iron smelting must be before us ere we can follow rationally the reactions which occur. The evolutionary process from the old bloomeries or Catalan forge, next the small blast-furnace up to the huge structures of to-day is clearly set forth. Credit is also given to the practical worker, who, the author acutely remarks, must have possessed more practical scientific knowledge than we have been inclined or able to perceive.

The apparent irrationality of the modern system of smelting, by which iron ore is not only reduced to the metallic state, but the resultant metal becomes loaded with silicon and carbon, &c., is fairly discussed. It is shown that although what is termed the direct process, *i.e.* the simple reduction of the metal from its oxide, may be so conducted as to produce a nearly pure wrought iron, yet such methods are not economical, and are of limited application.

The direct process (p. 85) demands rich ores; a great expenditure of fuel is incurred; simple and direct as it appears, a greater cost is involved; on the whole, it is better to resort to the ordinary purification of crude cast-iron by the puddling process. The relative merits of the direct process *versus* the ordinary practice of smelting and puddling, are, however, still under consideration. Recent investigations, combined with improved methods, indicate that at any rate in some localities the direct process may be advantageously applied. The modern blast-furnace is clearly described; the form, viz. a circular column swelling in diameter at both extremities, is commented upon, and sound reasons are adduced why this approximate form must be adhered to. Next (pp. 88–93) follows a brief but graphic picture of the behaviour of the mixed charge of ore, coke, &c., during its descent, from the charging to the final fusion of the iron in the crucible or hearth, which deserves careful reading.

The preliminary preparation of ores, *e.g.* drying, roasting, &c., previous to charging into the furnace, is strongly and rightly advocated. Iron manufacturers, however, are averse to anything entailing extra trouble and labour. It is the general opinion that, on the whole, little is gained practically, although theoretically the ordinary practice of charging raw material must, as the author says, entail considerable uncertainty during the subsequent smelting. We agree with Mr. Williams that the reactions of carbonic oxide and carbonic acid gases in the blast-furnace are even now not thoroughly understood; further, the part which solid carbon plays in the direct reduction of ores seems to us still somewhat mysterious. It is admitted that, when using soft coke, carbonic acid may be deoxidized, forming carbonic oxide. This occurs in the upper region of the furnace, and it is quite as probable that ore in contact with carbon may be also directly reduced in this part of the furnace. We have ourselves ascertained that, when intimately mixed oxide of iron and carbon are heated together, the reduction commences at a lower temperature than is usually supposed.

The theory of puddling is well discussed, and the working processes are lucidly explained. In addition the chemical reactions whereby purification is effected are given; also, as regards the elimination of sulphur and phosphorus, the work of Percy, Bell, and many others is ably summarized. The author also quotes his own results, derived from his experience and study, which, however, are not always quite in accordance with accepted ideas, but which nevertheless should be carefully considered.

Many pages are devoted to the question of what is steel; also fallacies concerning steel. Previous to the introduction of the Bessemer process, steel might be defined as a compound of carbon and iron, capable of being hardened, tempered, and welded. Steel containing $\frac{3}{4}$ per cent. of carbon was termed mild steel. The author states that by the Bessemer process steel is made as low as $\frac{2}{10}$ per cent. of carbon; really, however, large quantities of Bessemer steel, or rather metal are now cast with only $\frac{1}{10}$ per cent. carbon. The author does not mention this. One gathers that there is only one true steel, *i.e.* a compound of iron and carbon free from other constituents.

The old definition of steel, *i.e.* a compound of iron and carbon, is as true as ever, when applied as in the past to a material used for special purposes, viz. tools with cutting edges, &c.; but it would be perhaps more rational to say that the Bessemer product cannot in this sense be termed steel at all. It may be granted that a true steel is simply composed of iron and carbon, but such a material has its own particular uses; and should not be compared or confounded with the Bessemer product, where the very properties of being tempered, hardened, &c., with facility must be avoided. In proof of this it has recently been shown that Bessemer metal may be improved by the addition of small quantities of silicon, nickel, or even copper; also that for certain purposes a large quantity of manganese may be added to iron with advantage. Indeed, a well-known writer has gone so far as to hint that carbon may be eliminated altogether, and some other element advantageously substituted. It appears, therefore, that the author's definition of what is steel may in one sense be strictly true, yet may be inapplicable to the Bessemer product for the above reasons.

In chapter x., on fallacies concerning steel, the author reiterates that steel can only be manufactured from pure iron, showing clearly enough that many novel, promising processes have failed solely from the non-recognition of the necessity of freeing crude iron from certain objectionable elements.

The hardening, tempering, and testing of steel under varying conditions, also the cementation process, are discussed; as briefly put, they may be considered complete. The author's own investigations should be carefully studied. It is suggested that during the cementation process carbon itself is not transmitted, but that a soaking in of iron carbide occurs. A film of carbide is first formed on the surface of the metal; this unites or alloys with the layer of iron below; a lower carbide is formed which reacts in like manner, and so on to the interior; and borings taken from next to the surface, also at different depths below, indicate, as might be expected, varying properties of carbon. The gases occluded in the charcoal used for cementation appear to assist the reaction of carbon on iron. The writer has been informed that charcoal thus used becomes in time inert, having apparently lost occluded gas. Some metallurgists assert that carbon does not combine directly with iron, but recently this has been questioned, and it has been experimentally demonstrated that iron may combine with pure carbon. Discussing the *rationale* of cementation, it is suggested that possibly iron at a welding heat is really not a solid, but rather in a viscous, semi-fluid condition like sealing-wax or melted glass. Iron is thus rendered more porous to gases, and probably solids are thus absorbed. The experiments of Graham and others on the absorption of gases by iron seem in conformity; in fact, this absorption may be termed a species of cementation.

The Bessemer process is well described and its early history given; a clear explanation is afforded showing how the inventor's early anticipation that wrought or malleable iron could be manufactured direct was not realized, although the chemical reactions, viz. oxidation, &c., were similar in degree to those in the puddling furnace and refinery. Credit is given to Mr. R. Mushet, who first suggested the addition of spiegeleisen to the blown metal, thus converting a worthless material into the valuable material now termed Bessemer steel.

The chemical reactions of both the Bessemer and puddling processes are compared, and the necessity of using with the former a pure pig-iron free from sulphur and phosphorus clearly demonstrated. The primary reason given by Mr. Mushet for the addition of spiegel was that blown Bessemer metal contained an excess of oxygen in some form or other; and the triple compound of iron, manganese, and carbon was added with the sole object of removing oxygen, a slight excess being added to insure the necessary proportion of carbon. The author appears to have laid sufficient stress on this; the primary cause, according to Mr. Mushet, of the redshortness of the metal; and which is even now a difficulty, for it is known that oxygen cannot be entirely eliminated without the addition in many instances of an injurious excess of spiegel—the addition of silicon, and recently aluminum has been suggested, both favouring the elimination of oxygen.

P. 294. Viewing the Bessemer method as a purely chemical process, it is urged that chemical compounds, or solutions in admixture, will not always arrange themselves in the order of their chemical affinity; where a transfer of constituents can produce a solid compound, such transfer occurs as though the physical attraction of cohesion overpassed that of chemical affinity. Following this general rule, on which all chemical analyses are based, silicon (forming a solid) must go first; carbon follows; the rapid disappearance of manganese is due to its great affinity for oxygen; it also forms a solid silicate of manganese. Sulphur and phosphorus are not eliminated, owing doubtless to the small quantities present. This is hardly conclusive. The author says but little of the rapidity of the chemical reactions; and does not appear to have realized that ordinary chemical reactions may be modified in consequence of the abnormally high temperature attained during the Bessemer blow.

The influence of what may be termed mass has not been noticed; chemical affinities may thus be modified. Of two bodies in solution one may be greatly in excess of the other; on adding a precipitant it will be found that the element in excess is first precipitated, although the chemical affinity may be about the same or even greater for one element than the other. Barium sulphate is slightly soluble in acidified water, and it will be found that either barium or sulphuric acid may be precipitated at will by adding to the solution for the former a slight excess of sulphuric acid; for the precipitate of sulphuric acid it needs only to add a slight excess of a barium salt in lieu of sulphuric acid. As regards phosphorus, there can be no doubt that its presence is objectionable, and it is correct to say it injuriously affects the quality of any kind of steel. Sulphur is not so injurious.

The use of the spectroscope for controlling the blow is practically condemned; the author's experience, however, is not in accordance with that of other metallurgists. The basic process is shortly noticed, and the basic reaction summarized in a few words.

The part played by manganese as a steel improver is thoroughly discussed, the various theories are well ventilated, and the great affinity of this metal for oxygen insisted upon and emphasized. Manganese, however, when alloyed with iron in small quantities, can scarcely improve the quality. Mr. Hadfield's new alloys of manganese and iron cannot strictly be termed steel; the alloy possesses some of the properties of steel, and it may be compared to brass, which is not copper, but is, nevertheless, a substitute for copper, as candidly acknowledged by the author. His views as regards the mischievous action of small quantities of manganese contained in steel cannot be accepted in their entirety: they are certainly contrary to results of every-day practice in Bessemer steel works.

A theory of steel may be accepted as it is written; there can be little doubt as to the existence of a definite carbide of iron which alloys with metallic iron; although we have the alternative of assuming that carbon is simply difficultly soluble in molten or highly heated iron, yet the evidence seems in favour of the existence of the carbide. The properties which distinguish steel from crude iron are marked.

Alluding to the use and value of spiegeleisen, the author, curiously enough, confirms the old, nearly forgotten theory of Mushet, *i.e.* that for the steel manufacture, the triple compound of iron, manganese, and carbon is absolutely necessary. The carbide of iron, Fe_4C, must be more fusible than metallic iron, and some acute observations are made on the part which this fusible compound plays in the heating and cooling of steel under varying conditions. In other words, it is probable that the properties of hardening and tempering are thus conferred on iron, for this compound must be in a semi-fluid or plastic condition, whilst the iron is comparatively infusible. As liquids in cooling contract to a greater extent than solids, it is easy to imagine variations in temper or hardness due to the more or less rapid cooling of the steel. Sudden cooling must produce a violent molecular tension by the resistance of the rigid iron to the greater contraction, and variations in cooling, greater or less, must produce corresponding differences in the hardening or temper of steel. It is noted that, as regards solids, the coefficient of expansion is less than that of liquids; also, that the more fusible solids have a higher coefficient of expansion than the less fusible. This also plays a part in the production of the final product; and steel may be termed a *heterogeneous solid*, not homogeneous as usually assumed. Sir Lowthian Bell and Prof. Abel, however, assert that on heating piles composed of alternate layers of steel and wrought iron, the carbon contained in the former slowly diffuses, and the iron absorbs carbon from the steel. It is, therefore, probable that the heterogeneous solid of the author must, after repeated heatings, become practically homogeneous, and it follows that the so-called carbide, Fe_4C, may thus suffer decomposition.

In conclusion, after discussing the properties of alloys, particularly the alloy of sulphur and phosphorus with iron, the author ventures to state a general law, that the hardness of an alloy does not depend on the mean hardness of its constituents, but is harder than either of them, quoting numerous instances in support of this law. It is difficult to gainsay all this, and we recommend the theory of steel to the careful consideration of metallurgists. Other theories may be broached; for instance, carbon may, as before said, be soluble with difficulty in iron, and the proportion left in solution may depend on the rate of cooling, a portion remaining insoluble, showing its presence in the form of graphite or simply intermixed carbon. Prof. Akerman holds that carbon exists in iron in three different forms which may be distinguished; other well-known metallurgists confirm his views.

The following chapters, on iron *versus* steel for structural uses, and the stability of iron, are apparently ably written, and are recommended for the consideration of experts. The article on occlusion of gases in iron and steel is up to date. The researches of Graham, Deville, and Troost are quoted, and prominently those of Dr. Muller, to which latter the author appears to attach some importance. Iron, however, occludes other elements just as it does hydrogen—such as zinc, cadmium, magnesium, &c.; the same may be said even of carbon during the cementation process. Dr. Muller's method of collecting the gas by drilling gives no information as regards the gas actually occluded, which latter, it is evident, can only be extracted by heating in vacuum, as recommended by Prof. Roberts-Austen, and practised by Graham and Troost, also recently worked by Parry, Stead, and other chemists.

JOHN PARRY.

THE THEORY OF LIGHT.

The Theory of Light. By Thomas Preston. (London: Macmillan and Co., 1890.)

MR. PRESTON has written a valuable book on an important subject, one which will, as he hopes, be suited to the reading of junior students, and yet sufficiently full to meet the requirements of many who desire a more special acquaintance with the subject. At the same time it is difficult to avoid expressing the wish that he had carried the mathematical development of some parts of his subject a little further, and, if space required it, had omitted some of the more elementary details; though the work, within the limits laid down, is so well done, that criticism may seem ungenerous.

The historical method adopted in some parts of the book adds greatly to its interest, and the account given of the development of the subject, from the days of the Greek philosophers to the present time, will lead many to study the original sources of Mr. Preston's information with profit to themselves. It is a good thing for us to read how the first masters of the subject expressed themselves; to know what were the difficulties they felt, and what the problems which appeared important to their minds. We, who, thanks to Young and Fresnel, have had the difficulties that surrounded the wave theory in the time of Newton cleared away, are less apt than we might be at recognizing their magnitude, and at grasping the ingenuity and skill with which Newton treated the emission hypothesis, and the marvellous manner in which, in his hands, it was made to explain many of the phenomena of light.

In the earlier chapters of the book, after an explanation of the rectilinear propagation of light, a good deal of space is devoted to the explanation of phenomena usually dealt with under geometrical optics. The ordinary formulæ for prisms and lenses are deduced from the principle that the time from a point to its image is the same by all paths possible for the light—a principle which, in Lord Rayleigh's hands, has led to important results in the theory of optical instruments.

The argument given by Lord Rayleigh in his article in the "Encyclopædia Britannica," for showing that the effect of a wave is equivalent to half that of the first Huyghens zone, and that the phase of the disturbance is a quarter-period behind that from the pole, might with advantage have been given in greater fulness in Article 54 (the reference at the end of that article should be to Art. 154, Ex. 3).

The book is very complete so far as it goes, but the limits imposed by the author on himself do not allow him to show any very great originality in treating his subject, at least until we come to chapter ix., section iii., where he deals with the graphic method of solving problems in diffraction. In this section Cornu's beautiful method is employed, and many problems, usually only solved by analysis, are completely worked out by it.

The analytical solutions are, perhaps, a little hardly dealt with, as the methods of evaluating Fresnel's integrals given by himself, Gilbert, and Knochenhauer, only appear as examples. The theory of the diffraction gratings strikes us as being also rather brief. Rowland's concave gratings are best treated from the consideration that the waves from all the bright spaces arrive in the same phase. Possibly Bessel's functions are outside the limits of the mathematical treatment allowed by the author: if not, a reference to them would improve the treatment of the diffraction problems arising out of the case of a circular aperture.

Fresnel's theory of double refraction is given clearly in chapter xii., and the difficulties of finding a dynamical explanation of it are well stated. It is here, however, and in the chapter on the dynamical theory of reflection and refraction, that we think the limitation of the mathematical development unfortunate. The elementary theory of elastic solids is given sufficiently for optical purposes in several works accessible to students. The author might easily, if he had liked, have introduced a few pages of it in his own book. He would then have been able to give and discuss the theories of refraction and double refraction of both Green and Neumann, or McCullagh, and thus have added greatly to the value of the work.

The book is brought up to date in a satisfactory manner. The last chapter contains an account of the modern work on the electro-magnetic theory of light, including the recent experiments of Hertz.

ENGLISH PATENT LAW.

The Law and Practice of Letters Patent for Inventions; with the Patents Acts and Rules annotated, and the International Convention, a Full Collection of Statutes, Forms, and Precedents, and an Outline of Foreign and Colonial Patent Laws, &c. By Lewis Edmunds, D.Sc., (Lond.), F.C.S., F.G.S., of the Inner Temple, Esq., Barrister-at-Law; assisted by A. Wood Renton, M.A., LL.B., of Gray's Inn, Esq., Barrister-at-Law. (London: Stevens and Sons, Limited.)

THIS is a work of considerable pretensions. We see by his preface that Mr. Edmunds claims to have produced a comprehensive treatise, dealing exhaustively with Patent law and practice, and when we mention that the book runs, in this its first edition, to upwards of 900